Grant Title:

BOARD ON EARTH SCIENCES AND RESOURCES AND ITS ACTIVITIES

SUMMARY OF RESEARCH

January 15, 1995 - January 14, 1998

Principal Investigator: Dr. Craig M. Schiffries

Board on Earth Sciences and Resources
Commission on Geosciences, Environment, and Resources
National Research Council
Washington, D.C. 20418

Grant Number: NAG 5-2866

National Research Council
National Academy of Sciences/National Academy of Engineering
Commission on Geosciences, Environment, and Resources

BOARD ON EARTH SCIENCES AND RESOURCES AND THE U.S. GEODYNAMICS COMMITTEE

BOARD ON EARTH SCIENCES AND RESOURCES

The Board on Earth Sciences and Resources is the focal point for National Research Council activities in the solid-earth sciences, including issues related to research, education, the environment, geologic hazards, information management, and resource utilization. The Board conducts its activities through more than a dozen separately appointed committees and panels of volunteer earth scientists drawn from academia, industry, and government.

The Board's reports provide recommendations on national and international policy, address the state of science and technology, and review federal programs and agencies. They have been featured in Congressional hearings and briefings, formed the basis of an Executive Order signed by President Clinton and a recommendation in Vice President Gore's National Performance Review, and influenced national and international policy regarding scientific issues. NASA has announced that it will fly a dedicated satellite gravity mission similar to one described in *Satellite Gravity and the Geosphere: Contributions to the Study of the Solid Earth and Its Fluid Envelope* (1997; see Board Projects section below). The U.S. Congress has directed the Nuclear Treaty Programs Office of the Department of Defense to manage its research program in accordance with NRC recommendations in *Research Required to Support Comprehensive Nuclear Test Ban Monitoring* (1997; see Board Projects section below). The Board's activities have also been featured in the scientific literature, including *Science* and *Nature,* and the popular press, including newspapers, television, and national magazines.

U.S. GEODYNAMICS COMMITTEE

The U.S. Geodynamics Committee (USGC) fosters studies on the dynamic behavior of the Earth, with attention to both basic science and applications. Over the past two decades, the USGC has been instrumental in helping to start and to shape such important science programs as deep seismic reflection profiling, continental drilling, and geological transects across continent-ocean boundaries. The USGC also serves as the U.S. National Committee for the International Lithosphere Program.

In 1996, the role of the USGC was broadened to incorporate the activities of the Committee on Geodesy. Since 1975, this committee has conducted a wide range of studies on the scientific and technological applications of geodesy. Reports of the Committee on Geodesy have suggested actions to meet future societal and scientific needs in the areas of surveying, mapping, photogrammetry, and global space geodesy. Because of the vital importance of geodesy in a wide range of scientific issues, the Board on Earth Science and Resources has incorporated geodetic expertise in the USGC.

The U.S. Geodynamics Committee, including the Committee on Geodesy, completed three reports during the reporting period—*Satellite Gravity and the Geosphere: Contributions to the Study of the Solid Earth and its Fluid Envelope*, 1997; *Dynamics of Sedimentary Basins*, 1997; and *Airborne Geophysics and Precise Positioning: Scientific Issues and Future Directions*, 1995. These reports are described in the following list of accomplishments.

ACCOMPLISHMENT OF THE BOARD ON EARTH SCIENCES AND RESOURCES

Projects completed under the auspices of the Board on Earth Sciences and Resources during this reporting period are described below.

Effects of Past Global Change on Life

[National Research Council] — March 1995

This study is designed to help provide a scientific framework to assist the evaluation of the possible impacts of present and future global changes on the biosphere. Such a framework is based on the geologic record, which provides a unique, long-term history of changes in the global environment and of the impact of these changes on life. Because organisms are intimately related to their environment, we can infer that environmental changes of the past will have molded the history of life, and the geologic record confirms this inference for a wide range of temporal and spatial scales. The geologic record also reveals how particular kinds of environmental change have caused species to migrate, become extinct, or give rise to new species. More generally, it shows that many kinds of species and ecosystems are naturally fragile, and therefore transient, whereas other kinds are inherently more stable.

On the Full and Open Exchange of Scientific Data

[National Research Council] — March 1995

Science flourishes in an open environment, one that is fostered by unrestricted, nondiscriminatory, and affordable access to scientific data and information. The full and open exchange of scientific data and information has been the hallmark of international programs for addressing issues of the global environment. It is also consistent with U.S. information policy, as articulated in OMB Circular A-130. In recent years, however, an international trend to commercialize or restrict access to scientific data and information has emerged. This trend is embodied by proposed restrictions on the exchange of data through the World Meteorological Organization, which, if adopted, could curtail scientific investigations of global-scale problems. The report concludes that current international practices guaranteeing the full and open exchange of scientific data should, if anything, be expanded, not restricted.

A Data Foundation for the National Spatial Data Infrastructure

[National Research Council] — April 1995

This report calls for a common reference system for the generation, exchange, and integration of spatial data. The committee considers the NSDI foundation as the minimal directly observable or recordable data from which other spatial data are referenced and compiled. This foundation consists of geodetic control, orthorectified imagery, and terrain (elevation) data. The committee believes that the federal government should play a leading and facilitating role in coordinating the development of the foundation and to make those data available for public use and exchange.

Airborne Geophysics and Precise Positioning: Scientific Issues and Future Directions

[National Research Council] — May 1995

Scientists' understanding of geophysical processes has been limited by their inability to make accurate, precisely-positioned measurements. With the advent of the Global Positioning System (GPS), which enhances the ability to both navigate and position an aircraft, new scientific opportunities exist for high-resolution surveys of the topography and gravity field of the Earth. Such surveys have application in studies such as ice dynamics, active tectonics, resource assessment, hazardous waste characterization, nuclear verification, geodesy, global change, and hydrology. To fully utilize these new capabilities, however, airborne geophysics programs should be better coordinated and the geoscience community should have better access to aircraft and instruments. The report also recommends that the GPS signals be transmitted without encryption.

Mineral Resources and Sustainability: Challenges for Earth Scientists

[National Research Council] — February 1996

As applied to renewable resources such as timber or agricultural products the concept of sustainability seems relatively straightforward. But when applied to mineral resources there is little agreement on what is to be sustained or how. This workshop summary examines how earth scientists can help to formulate a better scientific basis for addressing this issue among themselves and with other concerned groups.

Maintaining Oil Production from Marginal Fields: A Review of the Department of Energy's Reservoir Class Program

[National Research Council] — April 1996

The Department of Energy's Oil Recovery Demonstration Program, is designed to help decrease the rate of abandonment of marginal oil wells and fields, and is expected to add about 1.5 billion barrels to domestic oil production by the year 2020. This volume analyzes whether the program has proven effective in demonstrating the application of conventional and advanced technology to prolong production in marginal oil fields.

Mineral Resources and Society: A Review of the U.S. Geological Survey's Mineral Resource Surveys Program Plan

[National Research Council] — April 1996

In response to a directive from Congress, the U.S. Geological Survey prepared a five-year plan for its Mineral Resource Surveys Program. The plan represents a significant departure from the past, and its implementation will likely result in significant changes in the direction of the USGS mineral resource activities. This report provides a critical scientific evaluation of the U.S. Geological Survey's Mineral Resource Surveys Program plan. It evaluates the scientific goals, balance, and significance of the plan with reference to the national need for minerals information and research.

Technical Issues in NOAA's Nautical Chart Program

[National Research Council] — June 1996

NOAA's paper nautical charts have been used historically for safe navigation of commercial, military, and recreational craft, as well as for coastal zone management. With the development of advanced ship navigation and piloting systems, there is a need for a digital information database that can meet new demands and adapt to rapid changes in technologies. *Technical Issues in NOAA's Nautical Chart Program* will examine the anticipated capabilities of NOAA's Automated Nautical Chart System and assess how effectively it will meet the requirement for a digital nautical information database. This study was conducted by a committee operating under the joint aegis of the NRC's Marine Board and the Mapping Science Committee (BESR).

High Performance Computing in Seismology

[National Research Council] — July 1996

Progress in the field of seismology is closely tied to advances in the technology for high performance computing. Seismologists in the petroleum industry are among the largest commercial users of supercomputers today. The analysis and modeling of earthquake processes, imaging of subsurface geologic structures, and operation of global networks for acquiring and archiving seismic data require the latest developments in computer and communications technology. This report surveys the status and opportunities for using high performance computing to address a range of critical scientific problems in seismology.

Rock Fractures and Fluid Flow: Contemporary Understanding and Applications

[National Research Council] — August 1996

Scientific understanding of fluid flow in rock fractures—a process underlying contemporary earth science problems from the search for petroleum to the controversy over nuclear waste storage—has evolved almost entirely in the past 20 years. This volume is the first-ever comprehensive report on the state of the field, with an interdisciplinary viewpoint, case studies of fracture sites, illustrations, conclusions, and research recommendations. The book addresses these questions: How can fractures that are significant hydraulic conductors be identified, located, and characterized? How do flow and transport occur in fracture systems? How can changes in fracture systems be predicted and controlled?

Dynamics of Sedimentary Basins

[National Research Council] — January 1997

Sedimentary basins are repositories of critical mineral and fossil-fuel resources, and they contain perhaps the most complete crustal record of lithospheric geodynamic processes. New tools and techniques have made it possible to interpret this record with ever greater precision and confidence, but further, significant advances will require insights from the basic sciences that can only come through multi-disciplinary, integrative research. This report by the U.S. Geodynamics Committee addresses this issue through an assessment of the emerging scientific techniques, data sets, and mult-disciplinary research opportunities for studies of sedimentary basins.

A Review of Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts

[National Research Council] — January 1997

Discrepancies between two sets of probabilistic seismic hazard analyses for some nuclear power plants led to an effort to (1) determine the cause of the discrepancies, and (2) propose a general methodology. The effort, co-sponsored by the U.S. Nuclear Regulatory Commission, the Department of Energy, and the Electric Power Research Institute, was undertaken by a Senior Seismic Hazard Analysis Committee (SSHAC). At the same time the U.S. Nuclear Regulatory Commission also requested that the National Research Council undertake an interactive review of the SSHAC study. This report is a critique of the SSHAC report and an evaluation of their suggested methodology.

The Future of Spatial Data and Society

[National Research Council] — March 1997

Public and private institutions are committing resources and making important long-term decisions concerning the collection, management, and use of spatial data. Although these actions are influenced by current pressures, priorities, and opportunities, their ultimate success depends on how these spatial data activities will be relevant to future needs and demands. The Mapping Science Committee hosted a workshop to consider how societal and technological changes that might occur within the next 15 years

might affect spatial data activities and vice versa. The workshop provided a framework for thinking about the future of the national spatial data infrastructure as society moves toward the information age. In many areas the problems of spatial data are merely echoes of much broader concerns; in others, they are comparatively unique.

Rediscovering Geography: New Relevance for Science and Society

[National Research Council] — April 1997

As political, economic, and environmental issues increasingly spread across the globe, the science of geography is being rediscovered by scientists, policymakers, and educators alike. Geography has been made a core subject in U.S. schools, and scientists from a variety of disciplines are using analytical methods and tools originally developed by geographers. *Rediscovering Geography* presents a broad overview of geography's renewed importance in a changing world. Through discussions and examples, this book illustrates geography's impact on international trade, environmental change, population growth, information infrastructure, the condition of cities, human health, and much more. This report provides a blueprint for the future of the discipline, recommending how both to strengthen its intellectual and institutional foundations and meet the demand for geographic expertise among professionals and the public.

Satellite Gravity and the Geosphere: Contributions to the Study of the Solid Earth and Its Fluid Envelope

[National Research Council] — August 1997

For the past three decades, it has been possible to measure the earth's static gravity field from satellites. Such measurements have helped answer questions about the structure of the earth's interior. Only recently, however, have new technological advances in instrument design made possible a satellite mission that could resolve the time-varying component of the global gravity field. These temporal variations are caused by dynamic processes that change the mass distribution in the earth, oceans, and atmosphere, and could be used to study a new class of important scientific problems. Based on an analysis of planned or envisioned mission concepts and the results of forward modeling, the report identifies the research priorities of a dedicated satellite gravity mission: ocean dynamics, including deep ocean circulation; continental water variation, including seasonal and annual variations in snow pack and groundwater level; sea-level change, including changes in the mass of the Greenland and Antarctic ice sheets; and post-glacial rebound. Satellite gravity measurements, in conjunction with other data, would also lead to improved geophysical models of the earth's crust, mantle, and atmosphere.

Research Required to Support Comprehensive Nuclear Test Ban Monitoring

[National Research Council] — August 1997

After years of negotiation, the Comprehensive Test-Ban Treaty (CTBT) was signed at the United Nations in September 1996. The treaty creates a need for global monitoring in the context of national and international efforts to control nuclear arms. To meet this technical challenge, the United States is at a time of pivotal decision-making with regard to the level and nature of basic research in support of CTBT verification. To address this problem, this study identifies the basic research questions in the fields of seismology, hydroacoustics, infrasonics, and radionuclide monitoring that should be supported to enhance the capabilities to monitor and verify the CTBT.

U.S. Symposium on Rock Mechanics

[Symposium sponsored by the U.S. National Committee for Rock Mechanics] — June 1997

The U.S. National Committee for Rock Mechanics (USNC/RM) sponsored the 36th U.S. Rock Mechanics Symposium at Columbia University on June 29 - July 2, 1997. The meeting was attended by approximately 500 scientists and engineers from more than 30 countries. In conjunction with the Symposium, the USNC/RM represented the United States in the International Society for Rock Mechanics, presented the 1997 awards for outstanding contributions in rock mechanics, and convened a committee meeting that featured two mini-workshops on (1) Rock Mechanics Issues Related to Penetrator Performance, and (2) Scientific Drilling Projects and Rock Mechanics Issues. The USNC/RM has transferred responsibility for hosting future U.S. Rock Mechanics Symposia to a recently formed scientific society.

Forum on International Geoscience

[Forum Convened by the Board on Earth Sciences and Resources] — November 1997

The Board on Earth Sciences and Resources joined with the American Geological Institute to host a Forum on International Geoscience. The Forum brought together representatives from the many sections of the nation's geoscience community to consider the role of the United States in international geoscience affairs. The presidents of three international geoscience unions—Robin Brett, International Union of Geological Sciences; Peter Wyllie, International Union of Geodesy and Geophysics; and Stephen Porter, International Union of Quaternary Research—appeared together for the first time in their organizations' histories. In addition, special presentations were made by Timothy Wirth, Undersecretary of State for Global Affairs; Sherwood Rowland, Nobel Laureate and Foreign Secretary of the National Academy of Sciences; Clark Burchfiel, Professor of Geology, Massachusetts Institute of Technology; Milton Ward, President, Chairman, and CEO of Cyprus Amax Minerals Company; Susan Morrice, CEO of S. Morrice and Associates; and David Simpson, President of Incorporated Research Institutions for Seismology.

FOSTERING THE EXCHANGE OF INFORMATION

The Board and its committees also serve as forums for fostering the exchange of information among scientists, engineers, and policy makers from government, universities, and industry. Keynote speakers at recent Board meetings include Undersecretary of State for Global Affairs Timothy Wirth, NSF Director Neal Lane, NOAA Administrator James Baker, Acting USGS Director Thomas Casadevall, USBM Director Rhea Graham, NASA Associate Administrator Ghassam Asrar, AGU President Sean Solomon, National Mining Association President Richard Lawson, and NAS Foreign Secretary Sherwood Rowland.

Issues discussed at recent Board meetings include the international role of U.S. geoscience, international environmental cooperation, globalization of the energy sector, the Global Disaster Information Network, an integrated global observing strategy for the global environment, material flows and public policy decisions, surface management regulation under the mining law, resources issues in the 105th Congress, mining and society, lessons learned from the closure of the U.S. Bureau of Mines, role of federal agencies in energy and mineral resources, earth science facilities and instrumentation, future challenges for an earth science agency, earth science priorities for the National Science Foundation, opportunities and challenges for the Mission to Planet Earth, continental scientific drilling, life in extreme environments, knowledge and distributed intelligence, rediscovering geography, the future of spatial data and society, the role of geosciences in ecosystem management, geoscience research in environmental restoration, the Government Performance and Results Act, education and employment trends for earth scientists, undergraduate science

education, continental scientific drilling, declassification of earth science data, science and creationism, and geology in the National Parks.

The Board and its committees are composed of individuals from industry, government, academia, and nongovernmental organizations. Recent appointments include Milton Ward (Chairman, President, and CEO of Cyprus Amax Minerals Co.), Richard Stegemeier (Chairman, President, and CEO, emeritus, of Unocal Corp.), Dianne Nielson (Executive Director, Utah Department of Environmental Quality), Edward Stolper (Chairman, Division of Geological and Planetary Sciences, California Institute of Technology), and Raymond Jeanloz (University of California, Berkeley). The Chairman of the Board is J. Freeman Gilbert of the University of California at San Diego. He was elected to the National Academy of Sciences for pioneering research in seismology that has greatly enhanced our understanding of the Earth. Like Mother Teresa di Calcutta, Pope John XXIII, and the Nobel Foundation, Freeman Gilbert is a recipient of a Balzan Prize awarded annually by the President of Italy.

Additional information on the Board's activities is provided on the World Wide Web at http://www2.nas.edu/besr.

NRC Board on Earth Sciences and Resources

The National Research Council (NRC) is the principal operating agency of the National Academy of Sciences and the National Academy of Engineering. It serves as an independent advisor to the government on scientific and technical questions of national importance.

The Board on Earth Sciences and Resources is the focal point for NRC activities in the solid-earth sciences, including issues related to research, education, the environment, geologic hazards, information management, and resource utilization. The board conducts its activities through more than a dozen separately appointed committees and panels. These bodies consist of leading scientists and engineers from academia, industry, and government.

The board's reports provide recommendations on national and international policy, address the state of science and technology, and review federal programs and agencies. Examples of recent reports that illustrate the diversity of the board's activities are discussed below.

Rediscovering geography

The NRC has a long history of studying advances in science and technology. A recent contribution to this tradition is *Rediscovering Geography: New Relevance for Science and Society* (National Academy Press, 1997), a broad overview of geography's renewed importance in a changing world. As political, economic, and environmental issues increasingly spread across the globe, the science of geography is being rediscovered by scientists, policy makers, and educators. Geography is now a core subject in U.S. schools, and scientists

from a variety of disciplines are using analytical methods and tools originally developed by geographers.

Through discussions and examples, *Rediscovering Geography* illustrates geography's impact on international trade, environmental change, population growth, information infrastructure, the condition of cities, human health, and other areas. This report provides a blueprint for the future, recommending how to strengthen the intellectual and institutional foundations that support the science of geography and ways to meet the demand for geographic expertise among professionals and the public.

Satellite gravity and the geosphere

Since the launch of Sputnik 40 years ago, scientists have tracked the orbital motions of satellites to detect variations in Earth's static gravity field. Such measurements have helped answer questions about the structure of Earth's interior. Only recently, however, have new technological advances in instrument design made possible a satellite mission that could resolve the time-varying component of the global gravity field by measuring gravity changes that are 100 to 100,000 times smaller than those measured previously. The increased power of resolution provided by these instruments is now sufficient to sense phenomena such as changes in gravity caused by the shifting of deep-ocean currents, an ice sheet melting in Antarctica, or seasonal snow pack accumulating on a mountain range. These changes in the distribution of water, snow, and ice mass are very useful for scientific research because they are associated with fluctuations in global climate change, ocean circulation, global sea level, and groundwater resources.

In light of these advances, a new NRC report entitled *Satellite Gravity and the Geosphere: Contributions to the Study of the Solid Earth and Its Fluid Envelope* (National Academy Press, 1997) examines various technical options for dedicated satellite gravity missions. These missions will provide new data in a variety of scientific fields, including solid-earth geophysics, oceanography, meteorology, and hydrology.

In the past, the costs of such missions were prohibitive. With advances in instrument technology, mission design, and gravity models, however, the cost of a dedicated satellite gravity mission has declined. The National Aeronautics and Space Administration recently agreed to fly the Gravity Recovery and Climate Experiment mission. This three- to five-year mission, similar to one of the satellite-to-satellite tracking missions described in NRC's satellite-gravity report, is scheduled for launch in 2001.

Comprehensive nuclear test ban monitoring

Last year, when President Clinton signed the Comprehensive Test Ban Treaty (CTBT) prohibiting all nuclear explosions worldwide, he recognized the need to strengthen the nation's capability to detect potential treaty violations. A recent NRC report, *Research Required to Support Comprehensive Nuclear Test Ban Monitoring* (National Academy Press, 1997), identifies specific research that will be needed for the United States to effectively monitor compliance with the treaty.

The CTBT creates a need for global monitoring in the context of national and international efforts to control nuclear arms. To meet this technical challenge, the United States must now make pivotal decisions with regard to the level and nature of basic research in support of CTBT verification. The NRC report identifies the basic research questions in the fields of seismology, hydroacoustics, infrasonics, and radionuclide monitoring that should be supported to enhance the monitoring and verification capabilities of the CTBT. Conducting such research, the report states, will require a substantial increase in current funding levels.

The report also emphasizes the importance of maintaining open access to monitoring data for scientific research. Noting that the treaty signatories have not yet defined a data access policy, the report recommends that the United States formulate and support a policy for open distribution of these data. Such access would strengthen research in support of treaty monitoring, increase confidence in verification efforts, and contribute to important research activities in other fields, including understanding global climate change and reducing hazards from earthquakes.

The U.S. Congress has directed the Nuclear Treaty Programs Office of the Department of Defense to manage its research program in accordance with NRC recommendations.

Reviews of federal programs and agencies

The Board on Earth Sciences and Resources routinely works with federal agencies to identify research opportunities, improve the quality of their research, and evaluate whether their research programs are aligned with societal goals. The NRC is undertaking an initiative entitled *Future Roles, Challenges, and Opportunities for the U.S. Geological Survey*. The USGS is at a critical juncture in its history. This study will provide independent advice about the agency's vision, mission, role, and scientific opportunities to help guide it into the 21st century. The NRC is also developing a study called *Basic Research Opportunities in the Earth Sciences at the National Science Foundation* to assist NSF in preparing its long-range plan for the earth sciences.

Craig M. Schiffries
Board on Earth Sciences and Resources, National Research Council, 2101 Constitution Avenue, N.W., Washington, D.C. 20418

Schiffries is director of the Board on Earth Sciences and Resources of the National Research Council. Activities of the board, along with on-line versions of many of its reports, are accessible through the World Wide Web: <www2.nas.edu/besr>.

NATIONAL RESEARCH COUNCIL NEWS

NATIONAL ACADEMY OF SCIENCES NATIONAL ACADEMY OF ENGINEERING INSTITUTE OF MEDICINE

Office of News and Public Information • 2101 Constitution Avenue, N.W., Washington, D.C. 20418 • (202) 334-2138

Date: July 2, 1997
Contacts: Ellen Bailey Pippenger, Media Relations Associate
Amy Kushner, Media Relations Assistant
(202) 334-2138; Internet <news@nas.edu>

[EMBARGOED: NOT FOR PUBLIC RELEASE BEFORE 5 P.M. EDT WEDNESDAY, JULY 2]

Publication Announcement

Geophysics Research Critical for Strengthening Efforts to Monitor Nuclear Test Ban Treaty

Two years ago when President Clinton signed the Comprehensive Nuclear Test Ban Treaty (CTBT) that prohibits all nuclear explosions worldwide, he recognized the need to strengthen the nation's capability to detect potential treaty violations. A new report from a National Research Council committee identifies specific research activities in the fields of seismology, hydroacoustics, infrasound, and radionuclide detection that will be needed if the United States is to effectively monitor compliance with the treaty. Conducting such a research effort will require a substantial increase in funding compared to current levels, the committee concluded.

Over the past 50 years, basic research in geophysics has provided the technical foundation for U.S. monitoring capabilities. By analyzing airborne radioactive particles and studying sound waves in the earth, the atmosphere, and the oceans, scientists have developed techniques to identify large-scale nuclear explosions anywhere in the world. Extending these methods to detect small-scale nuclear blasts, which also fall under the test ban treaty, will be a technical challenge, the report says. Many geophysical phenomena, including earthquakes, and such human activities as conventional mine explosions generate signals that might be mistaken for nuclear explosions.

Currently, 142 nations – including five with nuclear capabilities – have signed the Comprehensive Test Ban Treaty. For it to become effective, the treaty must be signed and ratified by all 44 countries that possess nuclear power reactors. To help countries detect violations of the test ban, the treaty specifies the establishment of an extensive international monitoring system to collect and process data from a global network of geophysical sensors. This information then will be transmitted to individual nations for use in their national treaty verification efforts.

A significant need exists for basic research to improve the analysis of these data, the report says. On a daily basis, the U.S. monitoring facility will have to analyze thousands of records, checking for trace evidence of a nuclear blast amidst the "background noise" of natural events and chemical explosions. A limited amount of basic research has been conducted in the field of seismology. And in some disciplines, nuclear monitoring research has been non-existent or dormant for more than 20 years. Undertaking a broad research agenda in seismology, hydroacoustics, infrasound, and radionuclides will be crucial, given this history and the challenge of monitoring the treaty.

(MORE)

The committee's key findings and recommendations are in the following areas:

• **Seismology.** Underground and underwater nuclear explosions can be detected by measuring the radiated seismic waves, but these must be distinguished from waves produced by earthquakes, volcanoes, quarry blasts, and other sources of ground vibration. Further study is needed to allow accurate worldwide monitoring of frequent, small seismic events that register below 4.0 on the Richter scale. Doing so will improve the capabilities of scientists to distinguish nuclear explosions from geophysical phenomena and human activities.

• **Hydroacoustics.** The ocean is an excellent medium for transmitting low-frequency sound waves, making it possible to detect underwater explosions from conventional or nuclear weapons. There is relatively little basic research, however, on the use of hydroacoustic signals to monitor such explosions. In addition, the report concludes that the proposed hydroacoustic monitoring network will have very limited capabilities. Because of these limitations, research is needed on combining hydroacoustic with other geophysical data to allow better monitoring of the world's oceans.

• **Infrasound.** Currently, the United States has only a few infrasound experts and thus has limited expertise available to support monitoring the atmosphere for low-frequency sound waves emitted by nuclear explosions. The country's monitoring operations have declined following the international ban on atmospheric nuclear testing in the 1960s. The Comprehensive Test Ban Treaty calls for a global system of infrasound sensors, as part of the new international monitoring system. To make use of the data from this system, the United States will need to conduct basic research that revamps its infrasound capabilities.

• **Radionuclides.** Particles and gases from a nuclear explosion have a distinct radiochemical signature. Detecting these properties in particles and gases dispersed by wind currents over thousands of miles will be a valuable part of a monitoring program. Drawbacks exist, however, because it will take several weeks to identify a possible nuclear explosion using these radionuclide measurements. To address this problem, enhanced research is needed to improve models that predict how radionuclides move through the atmosphere.

The committee also emphasized the importance of maintaining open access to the monitoring data for scientific research. Noting that the treaty signatories have not yet defined a data access policy, the committee concluded that the United States should formulate and support a policy for open distribution of CTBT data. Such access would strengthen research in support of treaty monitoring, increase confidence in treaty verification efforts, and contribute to important research activities in other fields, including understanding global climate change and reducing hazards from earthquakes.

The study was prepared for the Nuclear Treaty Program Office of the U.S. Department of the Defense, with funding from the Air Force Office of Scientific Research and the Defense Advanced Research Projects Agency. The National Research Council is the principal operating arm of the National Academy of Sciences and the National Academy of Engineering. It is a private, non-profit institution that provides science and technology advice under a congressional charter. A committee roster follows.

Copies of ***Research Required to Support Comprehensive Nuclear Test Ban Treaty Monitoring*** will be available in July from the National Academy Press; tel. (202) 334-3313 or 1-800-624-6242. Reporters may obtain copies from the Office of News and Public Information (contacts listed above.)

# # #

[This announcement is available on the World Wide Web at <www.nas.edu/new>.]

ebp: d2, d4, d5, g, k, l, m3, n

NRC backs open access to test-ban data

[WASHINGTON] Scientific researchers should have open access to data collected for monitoring the Comprehensive Test Ban Treaty, says a panel of the US National Research Council (NRC), the operating arm of the National Academy of Sciences. The panel also calls for a substantial increase in funding for research to improve test-ban monitoring.

Although the treaty states that its provisions "shall not be interpreted as restricting the international exchange of data for scientific purposes", concerns were raised about open access to the monitoring data during the negotiation of the treaty in Geneva. According to members of the NRC panel, sensitivity is likely to centre on radionuclide data, which might be used by environmental groups to identify leaks from nuclear power plants.

Some countries are also thought to have expressed a more general concern that making the monitoring data widely available will allow outside bodies — even the news media — to draw premature conclusions about potential treaty violations, before the parties to the treaty have had a chance to analyse the data fully.

But Thorne Lay, of the Institute of Tectonics at the University of California, Santa Cruz, and chair of the NRC panel, dismisses the "irrational concern that CNN might scoop the national data center". Lay says that media organizations lack the necessary seismic data-processing capability but that, if they had it, "they could do this right now" using publicly available seismograms.

The test-ban treaty has been signed by 142 countries including the five nuclear weapons states (the United States, Russia, China, France and the United Kingdom). It calls for the setting-up of an International Monitoring System, consisting of seismic, hydroacoustic, infrasound and radionuclide sensors around the world, and reporting back to an International Data Centre in Vienna.

About 10 gigabytes of data per day will reach the centre, which will then distribute information to data centres in each of the countries participating in the treaty. It has been left to the treaty's preparatory commission, currently meeting in Vienna, to draft a policy on the distribution of data beyond the national data centres.

The US government has yet to formulate a policy on this question. Steven Bratt, principal programme director for nuclear treaty programmes in the office of the Secretary of Defense, says that the United States plans "to have a position on this by the time it comes up in Vienna", but the issue is "not at the top of the queue".

In the meantime, however, the Air Force Technical Applications Center at Patrick Air Force Base in Florida, which has been providing a prototype US national data centre for an international test of the seismic component of the treaty monitoring system, has told US seismologists that, for the time being, it will not provide open access to data from stations outside the United States. "We can't make a decision about other countries' data," says Bratt.

The NRC panel's report, which was published last week, argues that open, near-real-time access to the data is essential to support the United States' ability to monitor the treaty and to allow for use of the data in other fields of basic and applied research.

For example, the 60-station infrasound network should provide important information on volcanic eruptions in remote areas, as well as helping to detect meteors entering the Earth's atmosphere. And the seismic data, if available in near real-time, will help in the rapid location and size estimation of earthquakes — information that could help to accelerate emergency response efforts.

Despite statements from defence department officials supporting open data access, seismologists in the academic community have expressed scepticism about the intention of the US national data centre to distribute data freely. "This was a classified arena," says one NRC panel member. "They aren't used to people looking [over their shoulders]."

The potential for difficult relations between the defence and academic communities has also arisen in the context of the funding of basic research to support the test-ban treaty. The NRC report outlines the research necessary to support the United States' test-ban monitoring goals, and concludes that substantially increased funding will be needed. Its rationale is that "there are major unsolved problems in seismology, and that there will soon be a substantial flow of data from [the other monitoring] systems for which there is far less operational experience".

But funding has decreased, from about $12 million per year in fiscal years 1995 and 1996 to $9.2 million in the present fiscal year. At the same time, the defence department's share of the funding ($8.8 million), previously split into separate lines for basic, exploratory-development and advanced-development research, has been consolidated into a single line controlled by the Nuclear Treaty Program Office (NTPO). This has prompted worries in the academic community that, as one panel member put it, "calibrating seismometers will suck up basic research money".

A more immediate concern is that the NTPO, through its administrative agent the Defense Special Weapons Agency, has apparently managed to spend only $3.8 million of the $8.8 million allotted to it. One seismologist suggests that the agency "was not used to dealing with basic research and the academic community. They're used to dealing with transfers to national labs, not small ($50,000–200,000) grants."

Steven Bratt of the NTPO admits: "We didn't do as well as we should have this year. Next year we're going to try to do better."

Laura Garwin

nature

10 July 1997 Volume 388 Issue no 6638

nature

10 July 1997 Volume 388 Issue no 6638

Tremors that should be public

The verification of the CTBT will provide data whose open availability would serve scientists and defence interests.

Few partnerships can have been as successful as the one that has existed, for the past forty years, between seismology and monitoring of underground nuclear tests. That the world now has a signed Comprehensive Test Ban Treaty (CTBT) is due in no small part to the past successes of seismological monitoring. And in turn, a generation of US seismologists has received generous funding from the Air Force for fundamental research.

With the signing of the CTBT, the science of test-ban monitoring is set to enter a new era. There should be a wealth of new data — from seismometers, but also from new networks of hydrophones, atmospheric pressure gauges and radionuclide detectors. Alas, there is no commitment by the US defence department to make these data available to the international scientific community (see page 107).

This state of affairs is worrying not just for research scientists but for the test-ban treaty itself. The problem of effective test-ban verification is far from solved, and the best solution to a difficult problem is to let as many bright people attack it as possible. Moreover, while openness may sometimes be inconvenient, a treaty such as the CTBT depends on mutual confidence, which can only be enhanced by free access to the data on which verification depends.

Thanks in part to the efforts of Vice President Al Gore, recent years have seen some welcome releases of previously classified datasets to the research community (see, for example, *Nature* **379**, 300–301; 1996). The signatories to the CTBT should not buck the trend. □

Remote sensing

Appreciate the gravity

Thomas A. Herring

Two satellites will soon be launched that can measure annual variations in the Earth's gravity due to mass changes equivalent to 1 cm of water over 250,000 km^2 — an area smaller than the Caspian Sea. This is gravity measurement of unprecedented accuracy. It will affect nearly all areas of study of the Earth, with the greatest advances expected in the study of ocean dynamics, continental water-table variations, sea-level rise, glaciology, and postglacial rebound. These possible applications were discussed at a meeting last month* and have been addressed in a National Research Council (NRC) report[1].

The first mission, CHAMP, is being developed in Germany with cooperation from the United States and France, and should be launched in 1999. CHAMP is a low-Earth orbiter whose main purpose is to study the Earth's magnetic field. However, it will be equipped with three global-positioning-system (GPS) receivers looking fore, aft and up. These receivers will be used to measure atmospheric refractivity (as GPS satellites go behind the Earth) and to refine our picture of the large-scale gravity field.

But the second mission, the Gravity Recovery and Climate Experiment (GRACE), to be launched by the US space agency NASA in 2001, is expected to provide the more detailed view of the changes in the Earth's gravity field. GRACE will be a pair of satellites, separated by a few hundred kilometres, and orbiting at an altitude of about 600 km for 3–5 years. These satellites will accurately measure changes in their separation, produced as they orbit the Earth following the bumps in its gravity field (Fig. 1). If the predicted measurement accuracy is realized, these satellites will give us a remarkably precise view of the Earth's gravity field and its fluctuation.

The gravity field provides a record of the Earth's mass distribution, and so can be used to understand the structure and dynamics needed to maintain that distribution. For the more fluid portions of the Earth, gravity measurements can be used to sense motions of mass. Calculating the mass distribution and dynamics from the gravity field is not a straightforward problem, but, through a combination of spatial and temporal analyses, insight can be gained into the processes that control these dynamics. For example, the distribution of mass in the mantle can be used to measure the vigour of mantle convection. The reliability of these inferences depends on the accuracy, spatial resolution, temporal resolution and duration of the gravity measurements.

The size of the mass changes GRACE can see depends on a number of factors. Perhaps counter-intuitively, it will be most sensitive to spread-out changes: the larger the area over which the mass change occurs, the larger the perturbations to the satellites' orbits. Also, the longer a mass change exists the more accurately it can be measured, because of the increased averaging time.

The NRC report[1] details the sensitivity of an imagined mission similar to GRACE by expressing mass changes as equivalent thicknesses of water over regions of different sizes, and over timescales of 90 days and up. For example, the groundwater level of the High Plains aquifer in the Great Plains region of the United States has fallen more than 30 m in places over the past 40 years[2]. This aquifer covers 750,000 km^2. Gradual changes over regions a third of this size should be measurable to an accuracy of < 5 mm yr^{-1} over a five-year mission; and annual variations of 10–30 mm over these same regions should also be detectable. Such integrated estimates of changes in the water volume would be hard to obtain with conventional hydrological measurements.

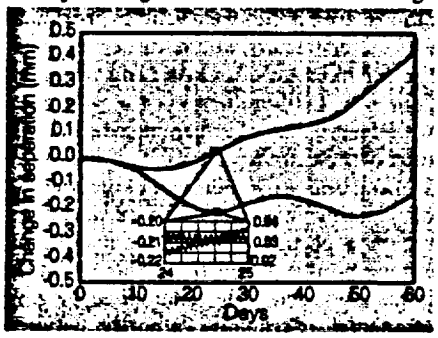

Figure 1 Sinuous grace: a simulation of the changes in separation between the two GRACE satellites, for two different mass changes on the Earth's surface. The satellites are assumed to be 400 km up in near-polar orbits, and at day zero, 1 cm of water is added over 250,000 km^2 at the Equator (red curve) and at 30° latitude (green). The deflections produced are much more than the expected measurement accuracy of 0.001 mm; the real problem will be subtracting the signal produced by the steady part of Earth's gravity field, a separation change of about 1 km with a periodic pattern like that in the insert.

Over the world's ocean, sea-level changes of < 1 mm yr^{-1} should be measurable, and, because the gravity mission will also detect the mass changes of the oceans, it will be possible to separate the thermal-expansion term of sea-level change from the water-mass term. Also, it should be possible to determine where the additional water is coming from — the current state of change of the world's large ice sheets, for example, is still poorly understood.

Interpreting changes in gravity is not without its problems. The mass distribution that generates a given external potential field is not unique. But most of the mass variations on timescales less than years are expected to arise from changes near the Earth's surface, and these *can* be inferred uniquely as surface mass densities. The atmosphere must be taken into account in the interpretation of these surface density changes, because it redistributes large masses and it is the most dynamic of the fluids in and on the Earth. In many regions of the world, existing models for atmospheric mass variations will probably be adequate to remove the atmosphere's contributions — but that will not be the case everywhere.

In addition to gravity changes, the next generation of gravity missions will greatly improve our knowledge of the static portion of the field. When combined with ancillary data (seismology, geology and laboratory measurements of materials at high pressure and temperature), the static gravity field should improve our understanding of the structure and evolution of the crust and lithosphere, and the processes involved in mantle dynamics and the deep structure of the Earth. □

Thomas A. Herring is in the Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, Massachusetts 02139, USA.
e-mail: tah@mitlas.mit.edu

*American Geophysical Union Fall Meeting, San Francisco, 8–12 December 1997.

1. *Satellite Gravity and the Geosphere* (Natl Acad. Press, Washington DC, 1997).
2. Dugan, J. T. & Cox, D. A. *US Geological Survey, Water Resources Investigations Report* 94-4157 (1994).

NATIONAL RESEARCH COUNCIL

NEWS

NATIONAL ACADEMY OF SCIENCES NATIONAL ACADEMY OF ENGINEERING INSTITUTE OF MEDICINE

Office of News and Public Information • 2101 Constitution Avenue, N.W., Washington, D.C. 20418 • (202) 334-2138

Date: May 28, 1997
Contacts: Ellen Bailey Pippenger, Media Relations Associate
Amy Kushner, Media Relations Assistant
(202) 334-2138; Internet <news@nas.edu>

[EMBARGOED: NOT FOR PUBLIC RELEASE BEFORE 5 P.M. EDT WEDNESDAY, MAY 28]

Publication Announcement

Satellite Missions to Map Earth's Gravity Field Offer Innovative Research Tools

Since the launch of Sputnik 40 years ago, scientists have tracked the orbital motions of satellites to detect variations in Earth's gravity field. During this era, satellites have revealed minute changes in gravity, which occur over great distances and long periods of time. This information has helped answer questions about the structure of the Earth's interior.

Only recently, however, have new technological advances in instrument design made possible a satellite mission that could detect far greater subtleties: gravity changes that are 100 to 100,000 times smaller than those measured previously, and which occur over weeks compared to years and in spans of 100 miles versus 500 miles. The resolving power of these instruments is sufficient to sense the changes in gravity caused by a deep ocean current shifting, an ice sheet melting in Antarctica, or seasonal snow pack accumulating on a mountain range. These changes in the distribution of water, snow, and ice mass are very useful for scientific research because they are associated with fluctuations in global climate change, ocean circulation, and ground-water resources.

In light of these advances, a new report from a committee of the National Research Council recommends satellite missions using newly developed instruments to map the Earth's gravity field. These missions would be targeted at providing new data in a variety of scientific fields, including solid-earth geophysics, oceanography, meteorology, and hydrology, with research priorities in the following areas:

• **Ocean dynamics.** Using data gathered by satellites, scientists can better determine sea-floor pressure variations. This information can be useful for studying deep ocean currents and, when combined with height measurements of sea-surface variations, can provide better models of ocean circulation. This data will help improve prediction of global weather patterns.

• **Continental water storage, including snow pack and ground water.** The amount of water stored in continents – such as snow, ground water, and runoff – varies greatly by season. Better detection of these changes would be valuable in long-term weather forecasting, global climate modeling, and assessment of the health of agricultural lands and major ground-water supplies. In addition, the hydrologic cycle – which is the exchange of water between the oceans, atmosphere, and upper crust of the Earth – could be measured more accurately.

(MORE)

• **Global sea levels.** The sources of global increases in sea levels are not well understood. Using satellite gravity experiments, scientists can better monitor changes in the continental ice sheets to comprehend their effect on sea levels. The report says that a five-year mission should be able to resolve whether the Greenland and Antarctic ice sheets are growing or shrinking.

• **Post-glacial rebound.** A complex process caused by the receding of glaciers – post-glacial rebound – is difficult to measure and interpret. Accurate gravity measurements will lead to major improvements in understanding changes in and viscosity of the Earth's mantle, which is the region between the crust and core.

• **Solid-earth processes and atmosphere dynamics.** Satellite gravity experiments, in conjunction with other data, will help scientists better measure and construct various geophysical models, including those of the Earth's crust, mantle, and atmosphere.

The report outlines different mission scenarios using one or two satellites. Two concepts for mapping the Earth's gravity field would involve a single satellite carrying a superconducting gradiometer – a high-precision instrument that measures differences in accelerations sensed by two masses in close proximity – to collect gravity data. Other scenarios include various forms of satellite-to-satellite tracking, in which two satellites are placed in the same orbit. Each is separated from the other by a few degrees, so that, in effect, one satellite "chases" the other. Mutual tracking between the two satellites provides data, yielding measurements of the global gravity field.

In the past, the costs of launching such missions were prohibitive. With advances in instrument technology, mission design, and gravity models, however, the expense of a dedicated satellite gravity mission has declined. And, in fact, NASA recently agreed to fly the Gravity Recovery and Climate Experiment mission. This three- to five-year mission, similar to one of the satellite-to-satellite tracking missions described in the committee's report, is scheduled for launch in 2001.

The study was funded by NASA. The National Research Council is the principal operating arm of the National Academy of Sciences and the National Academy of Engineering. It is a private, non-profit institution that provides science and technology advice under a congressional charter. A committee roster follows.

Copies of ***Satellite Gravity and the Geosphere: Contributions to the Study of the Solid Earth and its Fluid Envelopes*** will be available in July from the National Academy Press; tel. (202) 334-3313 or 1-800-624-6242. Reporters may obtain a copy from the Office of News and Public Information (contacts listed above).

# # #

[This announcement is available on the World Wide Web at <www.nas.edu/new>.]

ebp: c,d2,d3,d4,d5

Tracking Earth's attraction Very small changes in the Earth's gravity field—which might result from shifts in deep ocean currents, melting of ice sheets in Antarctica, or accumulation of seasonal snow pack in the mountains—could be detected and mapped using newly developed instruments on future satellite missions. A new report from the National Research Council recommends the satellite missions, which would detect gravity changes that are 100 to 100,000 times smaller than those measured previously, to map the Earth's gravity field and provide new data for a variety of scientific fields.

For example, the satellite data would help determine seafloor pressure variations, which would ultimately improve knowledge of deep ocean currents and the prediction of global weather patterns. Better detection of the amount of water stored in continents and its seasonal variation would be valuable in long-term weather forecasting, global climate modeling, and assessment of agricultural lands and groundwater supplies.

Data from satellite gravity experiments could help scientists understand the effect of continental ice sheets on sea levels. In fact, a 5-year mission could resolve whether the Greenland and Antarctic ice sheets are growing or shrinking. Finally, satellite gravity experiments will lead to major improvements in understanding changes in the Earth's crust, mantle, and atmosphere.—*Compiled by Elaine Friebele*

Contribution of Satellite Gravity Measurements to Earth Science, Global Change, and Natural Hazards Research (Joint with H, OS, T) (G41B, G42A)
With advances in instrument technology, mission design, and gravity models, the geopotential missions proposed today have the capability to collect data with sufficient accuracy to address a wide variety of Earth science problems. This session reviews the results of a National Research Council study on the application of satellite gravity measurements (both static and time-varying aspects with particular emphasis on the latter) for addressing research problems related to Earth science, global change, and natural hazards. Papers will address the application of time-varying gravity measurements to oceanography, solid Earth science, hydrology, glaciology and sea level rise studies, and will address error budgets for advanced gravity mapping mission, including GRACE, which has been selected as one of NASA's ESSP missions.

G41B **CC: 315** **Thurs 0830h**

Contribution of Satellite Gravity Measurements to Earth Science, Global Change and Natural Hazards Research I *(joint with H,OS,T)*

Presiding: J O Dickey, Jet Propulsion Lab

0830 h **G41B-01** *INVITED* Contributions of Satellite Gravity Measurements to Earth Science, Global Change, and Natural Hazards Research: **J O Dickey**, C R Bentley, R Bilham, J Carton, R J Eanes, T A Herring, W M Kaula, G S E Lagerloef, S Rojstaczer, W H F Smith, H M van den Dool, J M Wahr, M T Zuber

0845 h **G41B-02** *INVITED* Potential Hydrological Applications of Time-Dependent Gravity Measurements From Future Satellite Missions: **J Wahr**, S Rojstaczer, H van den Dool, R Eanes

0905 h **G41B-03** *INVITED* Solid Earth Applications of a Dedicated Satellite Gravity Mission: **M T Zuber**, R Bilham, J O Dickey, R J Eanes, T A Herring, W M Kaula, A Linn, W H F Smith, J M Wahr

0925 h **G41B-04** *INVITED* Potential New Insights Into Ocean Dynamics From Improved Satellite Gravity Measurements Combined With Satellite Altimetry: **G S Lagerloef**, J Carton, J M Wahr, R J Eanes, W H Smith

0945 h **G41B-05** *INVITED* Satellite Gravity, Ice Sheets, and Sea Level: **C R Bentley**, J M Wahr

1005 h **G41B-06** *INVITED* Error Analysis for Dedicated Earth Gravity Missions: **R J Eanes**, W H F Smith, J M Wahr, W M Kaula

---

NATIONAL RESEARCH COUNCIL NEWS

NATIONAL ACADEMY OF SCIENCES NATIONAL ACADEMY OF ENGINEERING INSTITUTE OF MEDICINE

Office of News and Public Information • 2101 Constitution Avenue, N.W., Washington, D.C. 20418 • (202) 334-2138

Date: April 1, 1997
Contacts: Craig Hicks, Media Relations Officer
Mark Parsons, Media Relations Assistant
(202) 334-2138; Internet <news@nas.edu>

[EMBARGOED: NOT FOR PUBLIC RELEASE BEFORE 5 P.M. EST TUESDAY, APRIL 1]

Publication Announcement

Deeper Understanding of Geography Key to Unraveling Society's Snarls

As the world around us shrinks and our lives become more directly affected by events that occur in mysterious places – from Bosnia to China to Zaire – the demand for geographic information grows even more critical for sorting out the issues of the day. The tools of geography help answer such perplexing questions such as:

- How do we revitalize urban areas ravaged by poverty?
- What can be done to stop the spread of disease from one region to another?
- How can we improve the way we predict natural disasters, such as floods, and adjust to them?
- How can we predict and mitigate the effects of global climate change?

Geographers play a major role in collecting and analyzing vast amounts of data to improve understanding of phenomena such as population growth, deforestation, international development, and regional conflicts. A new report by a committee of the National Research Council explores in detail the increasing significance of geography in education, research, and public policy. The report further outlines comprehensive steps that the geographic community and its constituents should take to strengthen the discipline to meet demands in the coming decades.

Citizens who are geographically literate are better equipped to explore, and comprehend, the world around them, the report says. To bolster geographic literacy, the report recommends that the United States launch a program to improve the understanding among adult citizens and leaders in the public and private sector. Geographic organizations should join forces with government, business, and non-profit groups to establish initiatives aimed specifically at adults, because the nation cannot afford to wait for future generations of geographically literate leaders. Such a program would supplement other actions the report recommends for upgrading the geographic education of American students.

At the same time, the geographic community should focus more of its limited research dollars on multidisciplinary projects that address major national and international problems, such as

(MORE)

global change, conflict resolution, and urbanization. These efforts would enable the geographic community to expand its contributions to society, despite the fact that the discipline is relatively small when compared with other natural and social sciences. Few universities have large geography departments, for example, and some leading schools have no geography programs at all.

Given these constraints, the examples of geography's many contributions cited in the report appear all the more remarkable. Geographic studies, for example, have helped explain:

- why poverty and prosperity concentrate and persist in certain geographic regions;

- how human activities, past and present, have changed local, regional, and global climates, and what effects those changes might have on food production and water supply systems; and

- how an epidemic like AIDS spreads and how health care services can be delivered more efficiently and effectively to deal with such outbreaks.

The report was funded by the Association of American Geographers, Environmental Systems Research Institute, Bureau of the Census, U.S. Department of Transportation, U.S. Environmental Protection Agency, National Geographic Society, National Science Foundation, U.S. Geological Survey, and the National Research Council.

The National Research Council is the principal operating arm of the National Academy of Sciences and the National Academy of Engineering. It is a private, non-profit institution that provides independent advice on science and technology issues under a congressional charter. A committee roster follows.

Copies of ***Rediscovering Geography: New Relevance For Science And Society*** are available from the National Academy Press for $34.95 (prepaid) plus shipping charges of $4.00 for the first copy and $.50 for each additional copy; tel (202) 334-3313 or 1-800-624-6242. Reporters may obtain copies from the Office of News and Public Information (contacts listed above).

# # #

[This news release is available on the World Wide Web at <www2.nas.edu/new/]

ch: d